



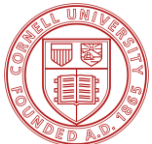
**Barcelona
Supercomputing
Center**
Centro Nacional de Supercomputación



**UNIVERSITAT POLITÈCNICA
DE CATALUNYA
BARCELONATECH**

Assessment of modelled dust mineralogy with multiple Earth System Models

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Jan Perlwitz, Philip G. Brodrick, Robert O. Green, David R.
Thompson, Oriol Jorba, Carlos Pérez García Pando.

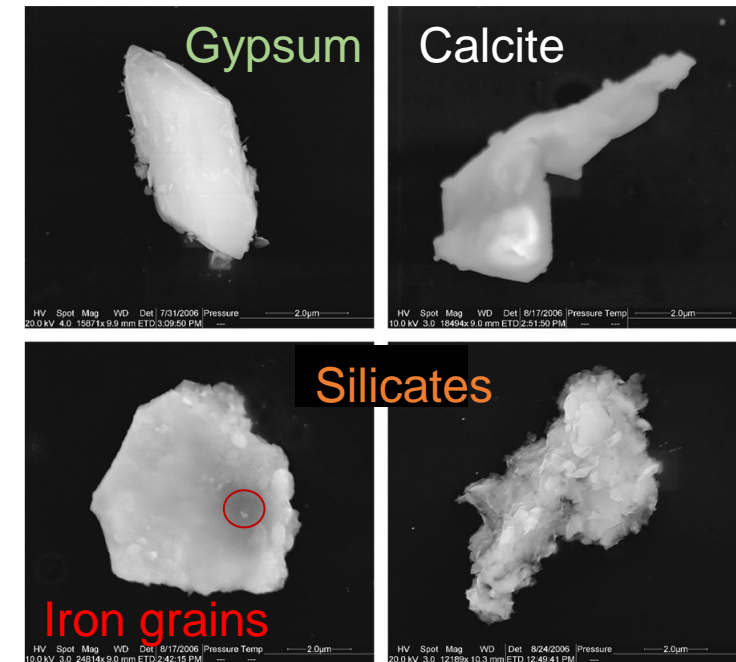
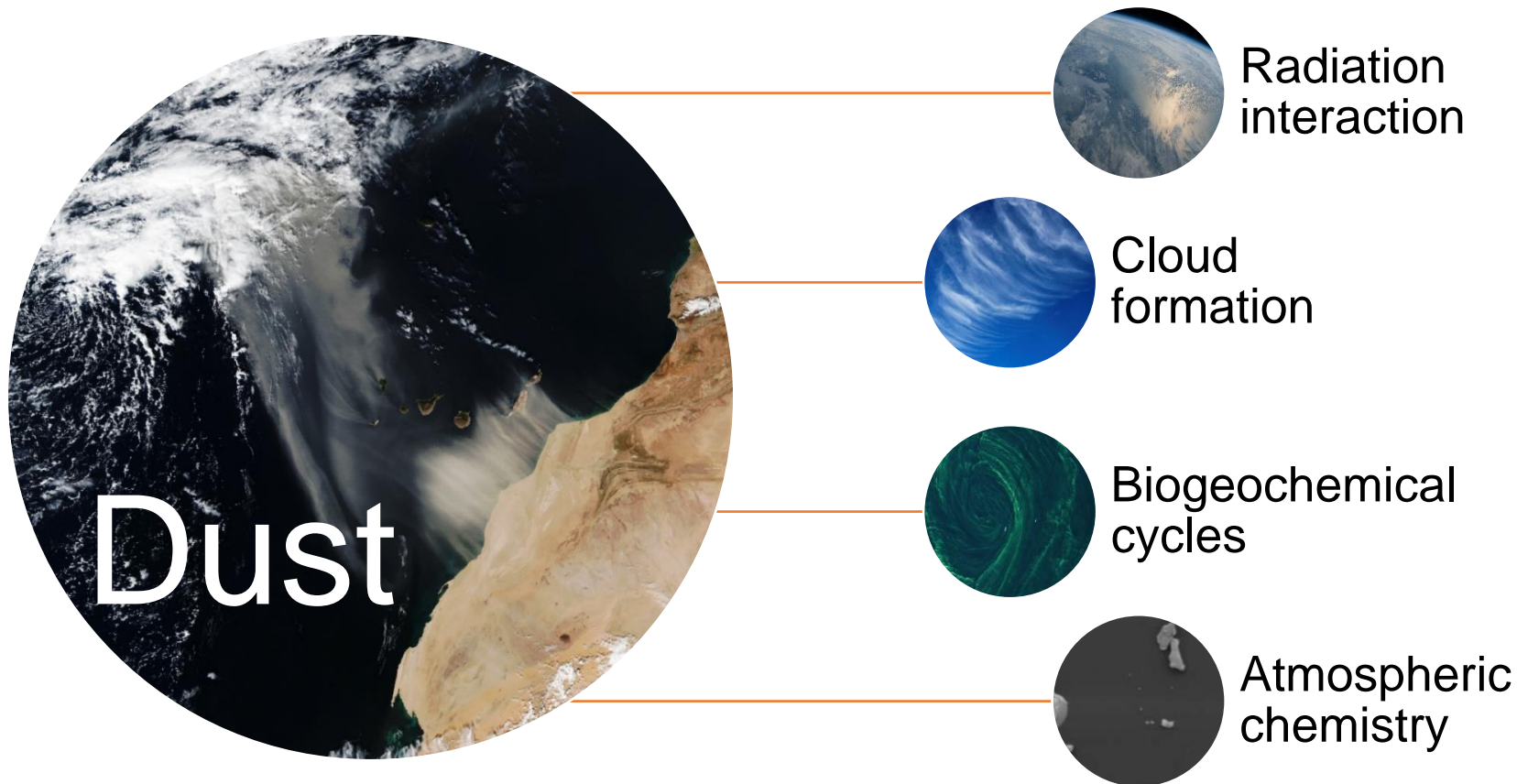


**Climate, Aerosol, and
Pollution Research**



21th AeroCom /10th AeroSAT meeting

Oslo, 10/10/2022



Kandler et al. (2007)

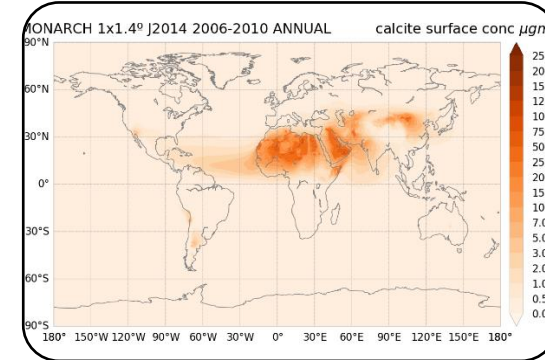
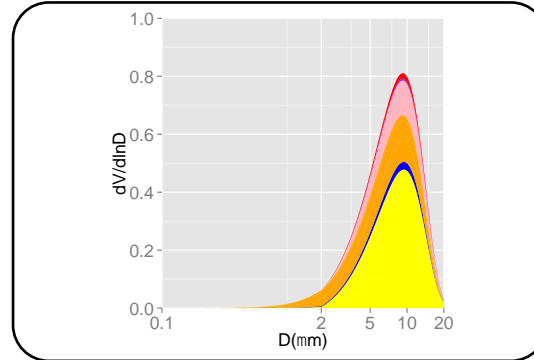
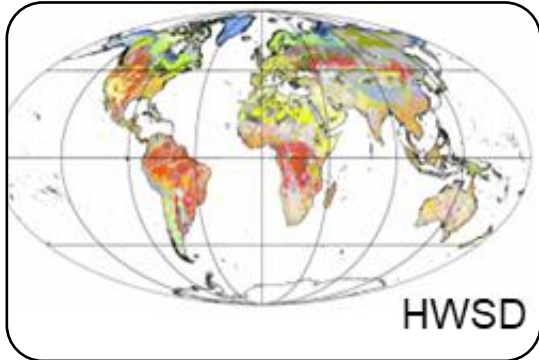
... these impacts are modulated by mineralogy.

Image credits: NASA, NOAA, Krueger et al. (2004)

Goal

- More and more, Earth System Models (ESMs) are including dust mineralogy in their frameworks, with different levels of complexity.
- Overview of the **variability in modelled dust mineralogy** produced by different state of the art atmospheric and ESMs: **CESM-CAM6, GFDL-AM4, IFS-AER, GISS-ModelE** and **MONARCH**.
- Provide an **evaluation of the modelled mineral mass** fractions against observations.

Modelling dust mineralogy



Soil
mineralogy

Emitted
size-
resolved
mineral
fractions

Minerals'
atmospheric
cycle

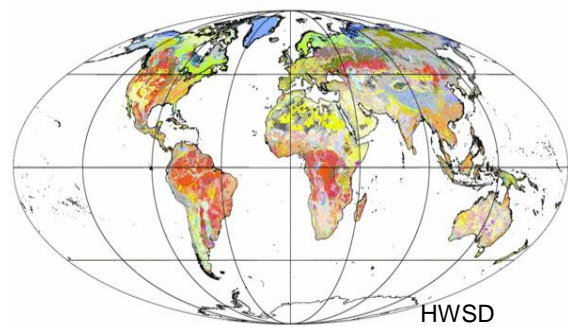
Global soil mineralogy atlases

- **Claquin et al. 1999, Nickovic 2012:** 8 minerals.

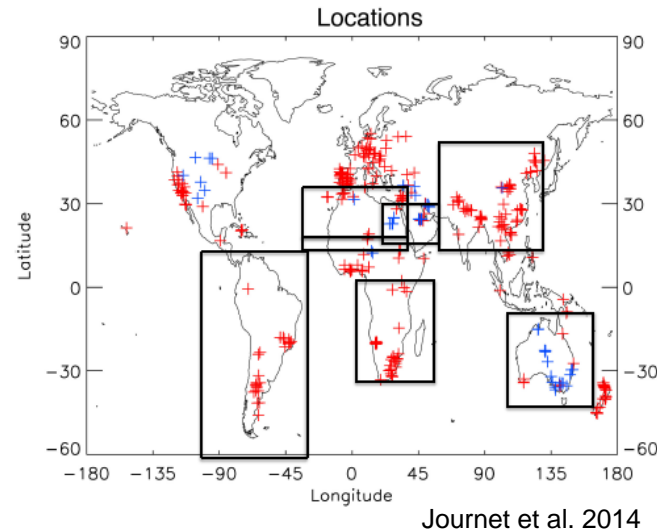
Illite, smectite, kaolinite, quartz, feldspars, calcite, gypsum and hematite (iron oxides).

- **Journet et al. 2014:** 12 minerals.

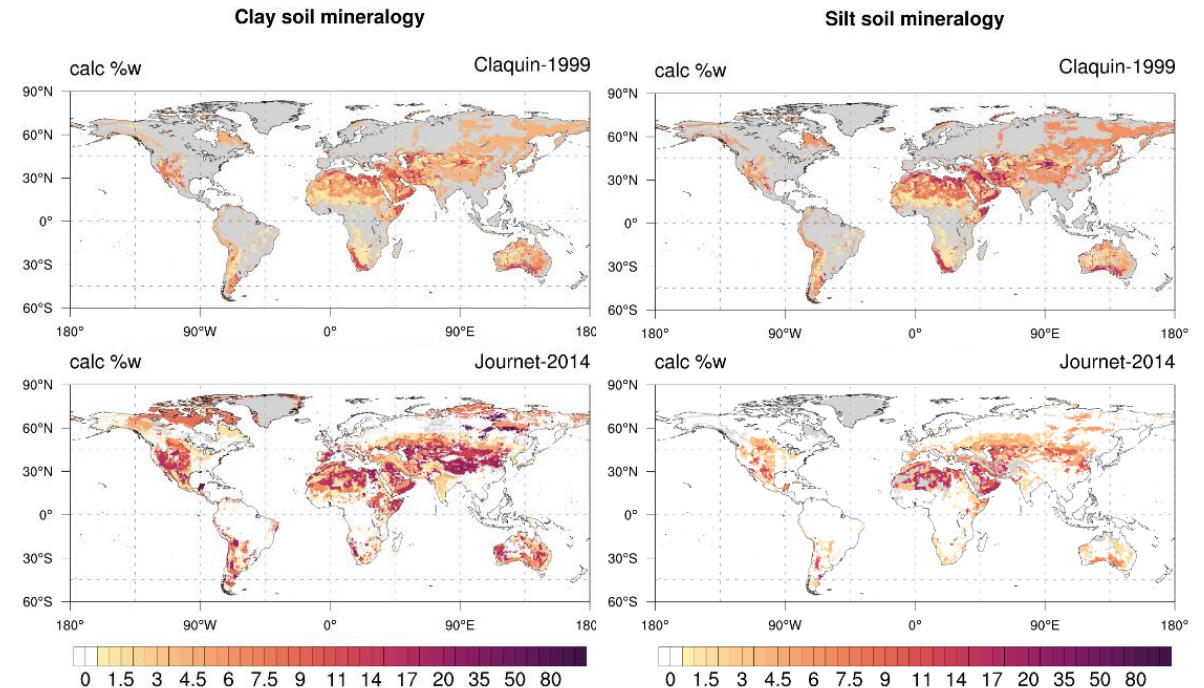
Illite, smectite, kaolinite, vermiculite, chlorite, mica, quartz, feldspars, calcite, gypsum, hematite and goethite.



FAO soil classification

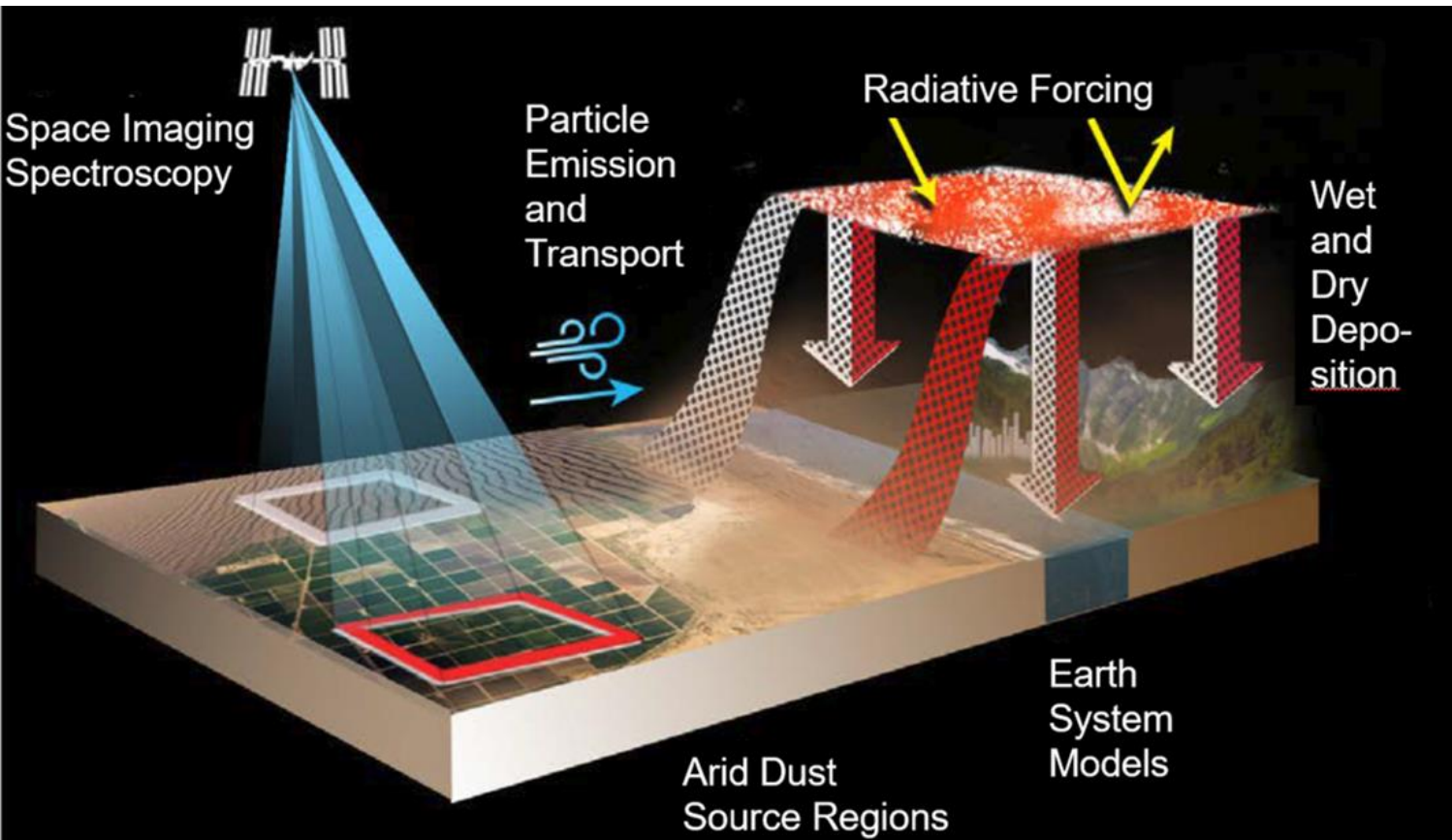


Mean mineralogy



Mineralogical composition for
clay ($\phi < 2 \mu\text{m}$) and silt ($\phi 2\text{-}63 \mu\text{m}$) size classes

Ongoing EMIT NASA mission



Map of the mineralogy of dust sources at high resolution

Abundance of 10 minerals
(to be complemented with additional methods for quartz and feldspars)

Input for ESMs

Green et al. (2020)

Model characteristics

Model	CESM-CAM6	MONARCH	GFDL-AM4	GISS-ModelE	IFS-Aer
Soil mineralogy	C1999	C1999 J2014	C1999	C1999	J2014
PSD	Modal model 3 modes	Sectional model 8 bins	Sectional model 5 bins	Sectional model 5 bins	Sectional model 3 bins
Size range (diameter)	10 μm	20 μm	20 μm	32 μm	40 μm
Emission method	BFT	BFT	BFT	Modified BFT	Projected
Mixing state	Internally mixed	Externally mixed Fraction of iron oxides mixed with other minerals	Externally mixed Fraction of iron oxides mixed with other minerals	Externally mixed Fraction of iron oxides mixed with other minerals	Externally mixed
References	Scanza et al. (2015), Hamilton et al. (2019), Li et al. (2021)	Gonçalves Ageitos et al. (in. prep), Klose et al. (2021)	Horowitz et al. (2020)	Obiso et al. (in prep), Perlwitz et al. (2015a,b)	Remy et al. (2022)

Variability across models: same soil map.

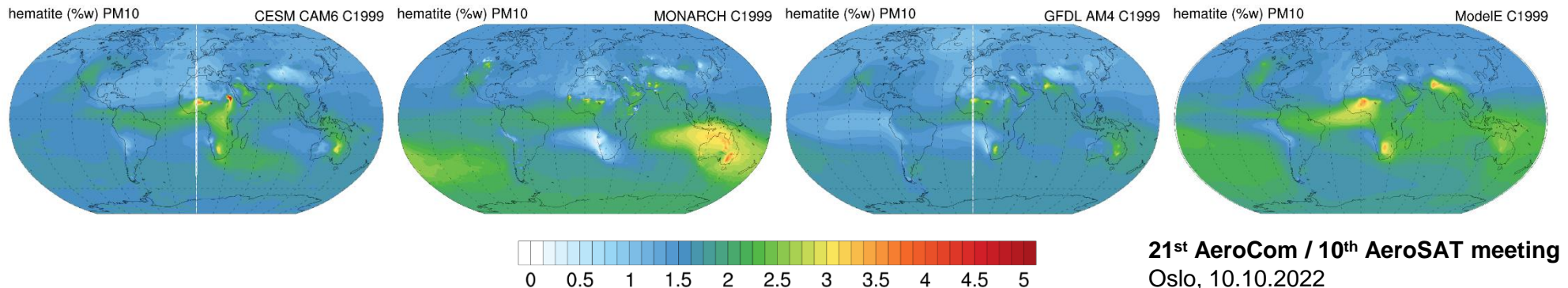
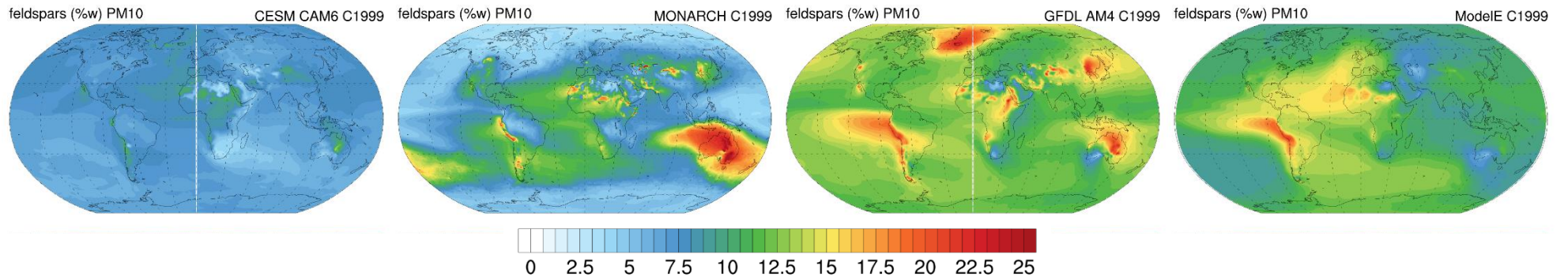
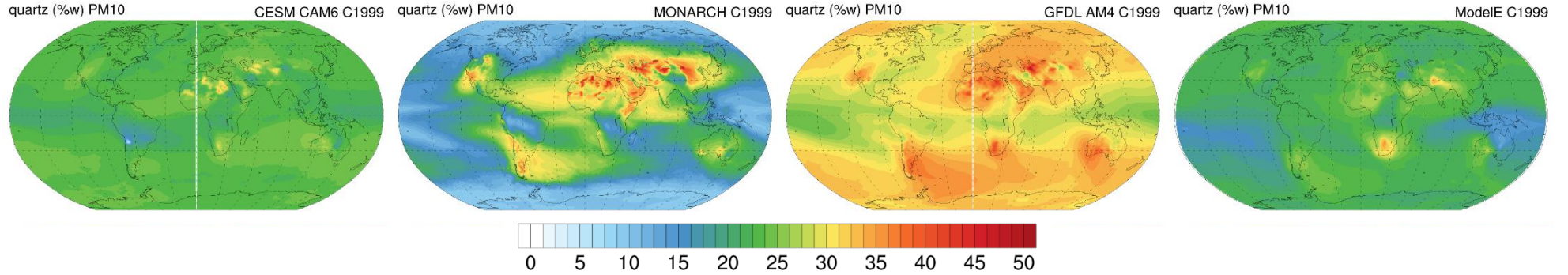
Mineral mass fractions at surface PM10 concentration.

CESM-CAM6

MONARCH

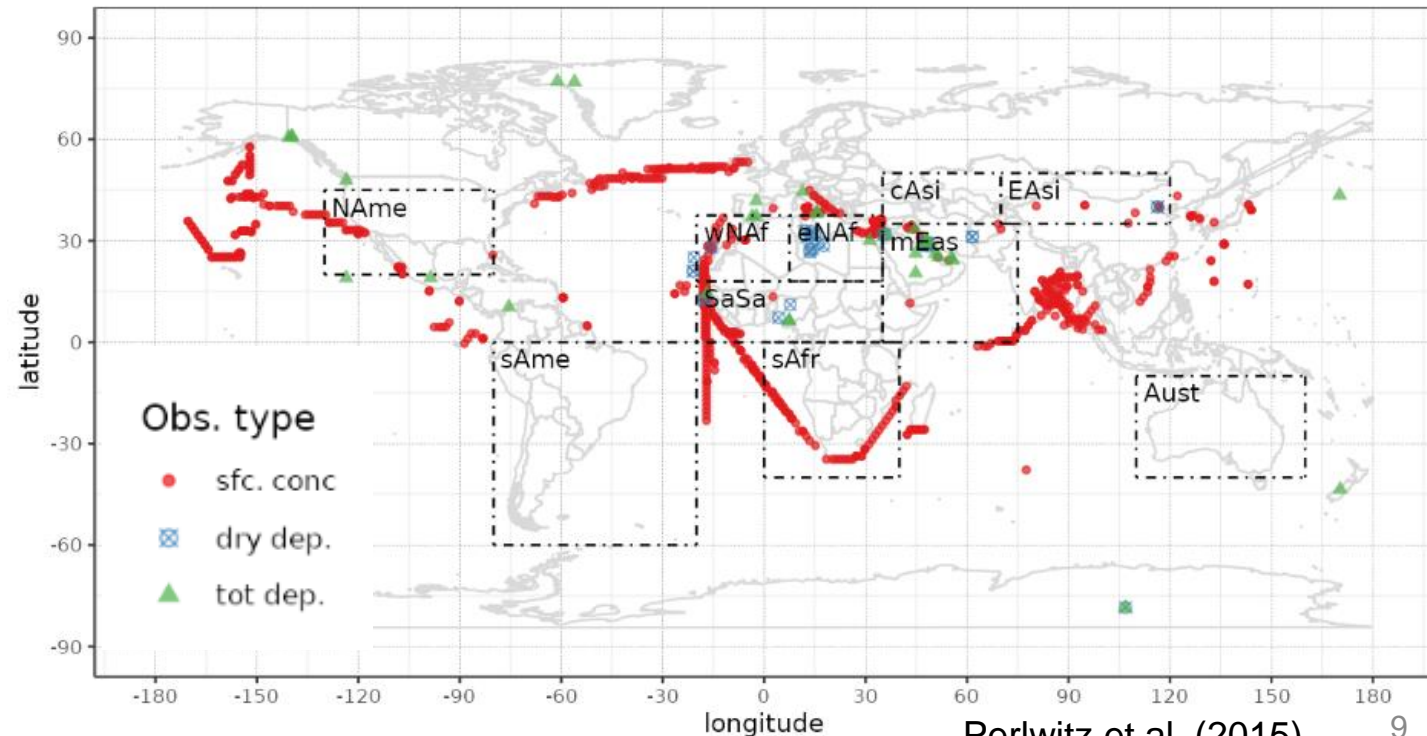
GFDL-AM4

GISS-ModelE



Observations of mineral mass fractions

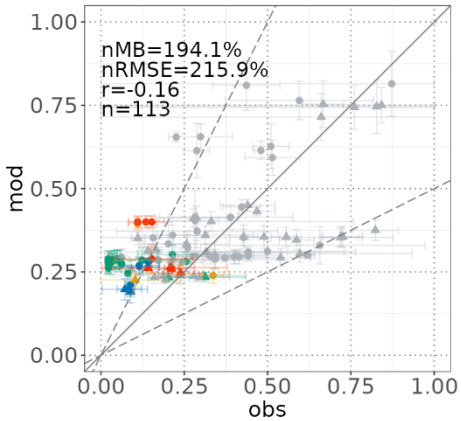
- Obs. from the late 60's to date.
 - Sampling time vs. model average: Temporal collocation – monthly basis
 - Reported minerals vs. modelled minerals: Mineral fractions estimated over those minerals observed AND modelled
 - Size range of observations vs. modelled size range: Size collocation
-
- Statistics in the plots use data in the modelled size ranges.
 - Normalized Mean Bias (nMB)
 - Normalized Root Mean Square Error (nRMSE)
 - Correlation (r)
 - Number of measurements in the samples used for the comparison (n)



Quartz mass fraction evaluation

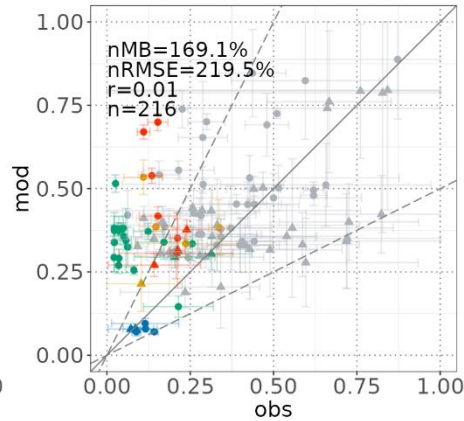
CESM-CAM6

quar mass ratio
CAM6 C1999 2007-2011



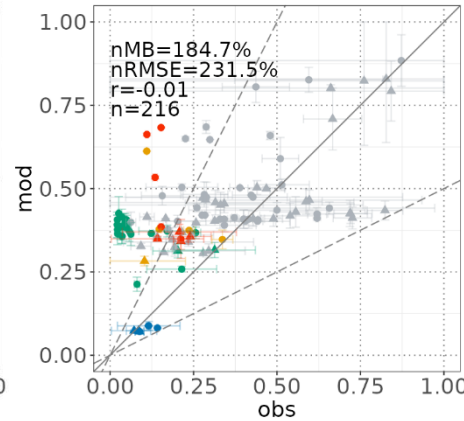
MONARCH

quar mass ratio
MONARCH C1999 2006-2010



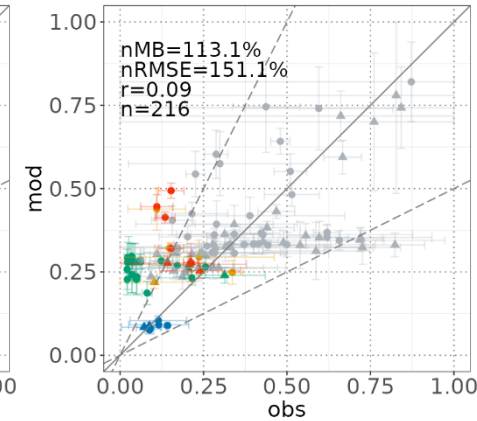
GFDL-AM4

quar mass ratio
GFDL-AM4 C1999 2002-2006



GISS-ModelE

quar mass ratio
ModelE C1999 2011-2020

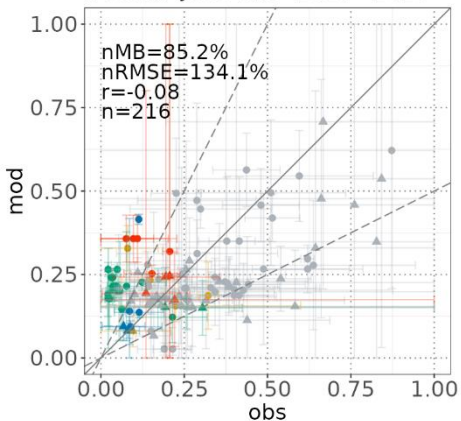


Size range

- <2um
- <10um
- <20um
- bulk
- 2-20um

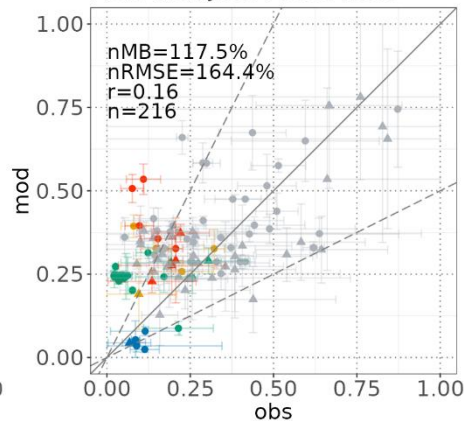
IFS-AER

quar mass ratio
IFS-AER J2014NN 2017 - 2020



MONARCH

quar mass ratio
MONARCH J2014 2006-2010



Size range

- <2um
- <10um
- <20um
- bulk
- 2-20um

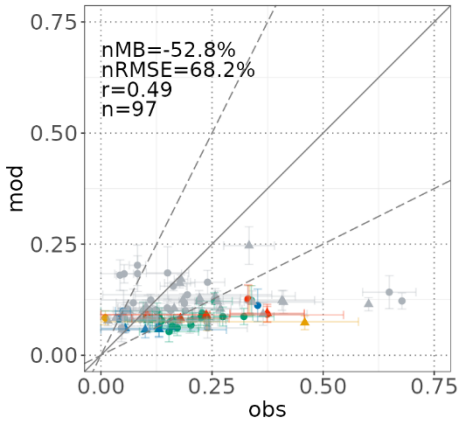
Overestimation of the mass fraction above 2 μm of diameter across models.

Some models also show an underestimation in clay sized fractions (below 2 μm of diameter).

Feldspar mass fraction evaluation

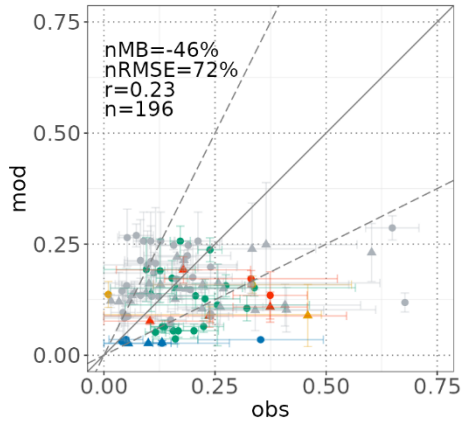
CESM-CAM6

feld mass ratio
CAM6 C1999 2007-2011



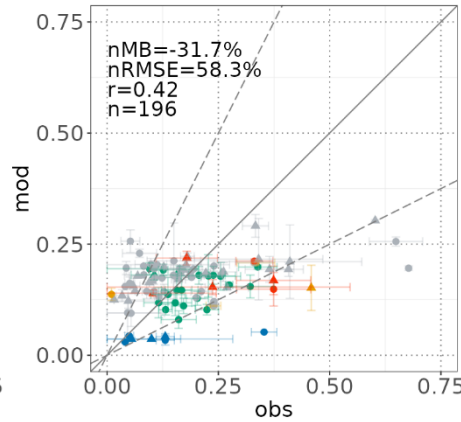
MONARCH

feld mass ratio
MONARCH C1999 2006-2010



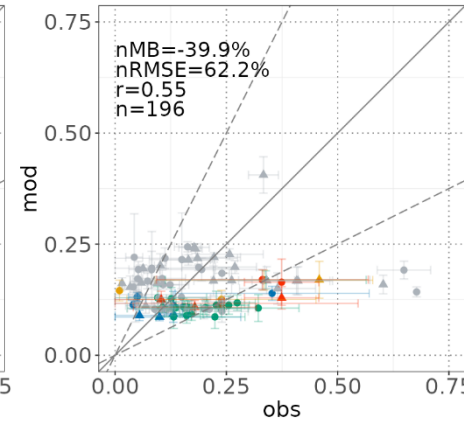
GFDL-AM4

feld mass ratio
GFDL-AM4 C1999 2002-2006



GISS-ModelE

feld mass ratio
ModelE C1999 2011-2020

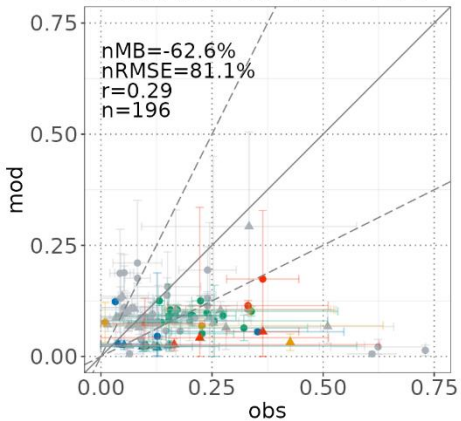


Size range

- <2um
- <10um
- <20um
- bulk
- 2-20um

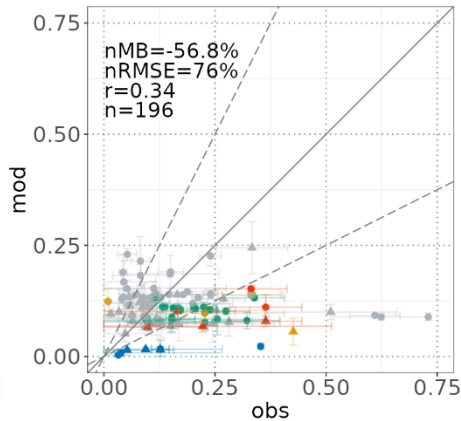
IFS-AER

feld mass ratio
IFS-AER J2014NN 2017 - 2020



MONARCH

feld mass ratio
MONARCH J2014 2006-2010



Size range

- <2um
- <10um
- <20um
- bulk
- 2-20um

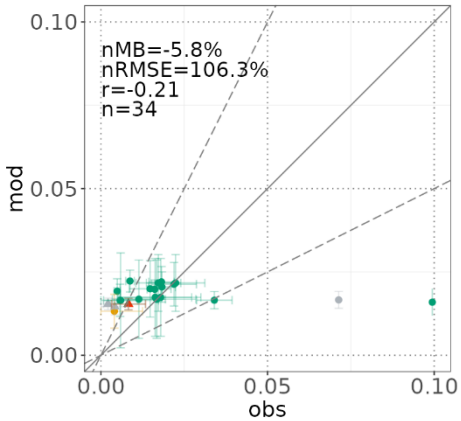
Better correlation between models and observations for the feldspars mass fraction than for quartz (less observations).

Underestimation of the mass fraction above 2 μm of diameter across models.

Iron oxides mass fraction evaluation

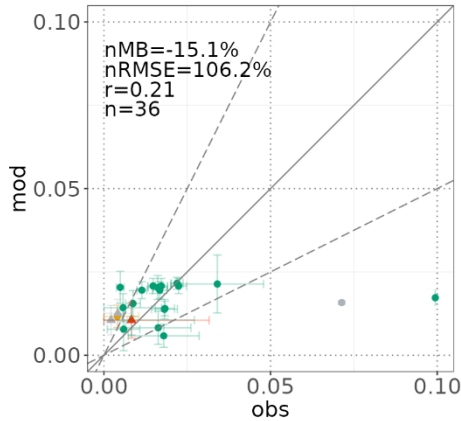
CESM-CAM6

irox mass ratio
CAM6 C1999 2007-2011



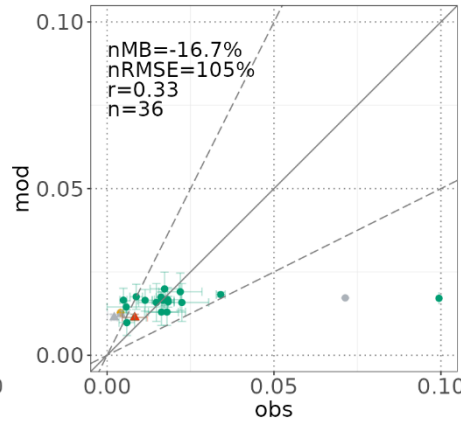
MONARCH

irox mass ratio
MONARCH C1999 2006-2010



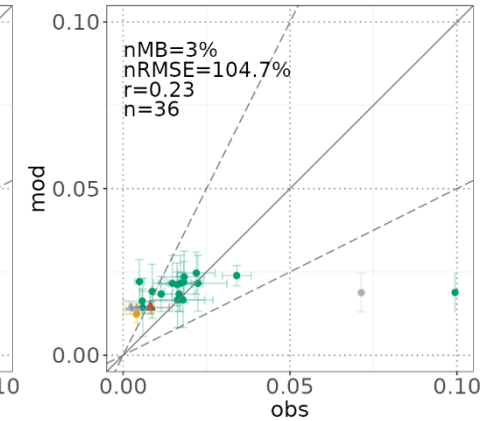
GFDL-AM4

irox mass ratio
GFDL-AM4 C1999 2002-2006



GISS-ModelE

irox mass ratio
ModelE C1999 2011-2020

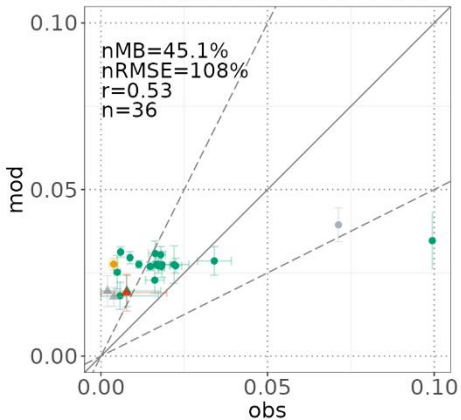


Size range

- <2um
- <10um
- <20um
- bulk
- 2-20um

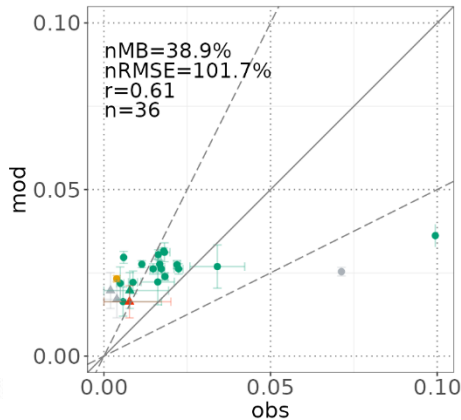
IFS-AER

irox mass ratio
IFS-AER J2014NN 2017 - 2020



MONARCH

irox mass ratio
MONARCH J2014 2006-2010



Size range

- <2um
- <10um
- <20um
- bulk
- 2-20um

Improved spatio-temporal distribution of iron oxides in models that use the Journet et al. (2014) soil map.

Underestimation in models using Claquin et al. (1999) and overestimation in models using Journet et al. (2014).

Conclusions

- Dust mineralogy is increasingly present in Earth System Models with the aim of improving the representation of dust climate interactions.
- Despite the large variability across models, the evaluation metrics are overall similar when compared to our reference observational dataset.
- Our current knowledge of the composition of dust sources is limited, and ultimately determines the models' ability to reproduce the minerals' atmospheric cycle.
- Additional adjustments to define the size-distributed mineralogy at emission may be key to solve the overestimation of quartz in silt sizes, and in turn improve the feldspars representation.
- Including goethite within the modelled iron oxides results in a slightly better comparison with observations. The reason for this improvement has to be further explored (increased mass, speciation, spatial distribution).
- Our results support the need for further observational constraints, both to better characterize the soils and to assess the airborne dust composition.
- Ongoing projects, such as EMIT or FRAGMENT, will provide key new information for the modelling community.

Thank you !

Acknowledgments

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- The research leading to these results has also received funding from the Spanish Ministerio de Economía y Competitividad as part of the NUTRIENT project (CGL2017-88911-R), the H2020 GA 821205 project FORCeS, and the ESA-DOMOS project.
- We thankfully acknowledge the computer resources at Marenostrum4, granted through the PRACE project eFRAGMENT2 and the RES project AECT-2020-3-0020; the technical support provided by the BSC, and the work of all the members of the BSC Earth Science Department group who contribute to the MONARCH model and infrastructure developments.
- Thanks to all the providers of the observational data used for the model evaluation.



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